US009411822B2

(12) **United States Patent**
Lynch

(10) **Patent No.: US 9,411,822 B2**
(45) **Date of Patent: Aug. 9, 2016**

(54) **SYSTEM AND METHOD OF GENERATING AND USING OPEN SKY DATA**

(71) Applicant: **Navteq B.V.**, Veldhoven (NL)

(72) Inventor: **James D. Lynch**, Chicago, IL (US)

(73) Assignee: **HERE Global B.V**, Veldhoven (NL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/319,911**

(22) Filed: **Jun. 30, 2014**

(65) **Prior Publication Data**

US 2014/0314326 A1 Oct. 23, 2014

Related U.S. Application Data

(62) Division of application No. 12/756,338, filed on Apr. 8, 2010, now Pat. No. 8,786,845.

(51) **Int. Cl.**

G06F 17/30	(2006.01)
G01C 21/36	(2006.01)
G01C 21/32	(2006.01)

(52) **U.S. Cl.**

CPC ***G06F 17/30241*** (2013.01); ***G01C 21/32*** (2013.01); ***G01C 21/3691*** (2013.01); ***G06F 17/3087*** (2013.01)

(58) **Field of Classification Search**

CPC G06F 17/30; G01C 21/36

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,949,268	A *	8/1990	Nishikawa et al.	701/454
6,711,475	B2	3/2004	Murphy	
6,917,893	B2	7/2005	Dietsch et al.	
7,302,359	B2	11/2007	McKitterick	
2004/0130702	A1	7/2004	Jupp et al.	
2008/0208455	A1	8/2008	Hartman	
2009/0122295	A1	5/2009	Eaton	
2009/0225155	A1	9/2009	Hirotani	
2009/0254274	A1	10/2009	Kulik et al.	
2009/0262974	A1	10/2009	Lithopoulos	
2009/0322742	A1	12/2009	Muktinutalapati et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

WO	WO2009016242	2/2009

OTHER PUBLICATIONS

GNS 430(A) Pilot's Guide and Reference, Dec. 2009, 190-00140-00 Rev. P, Garmin.

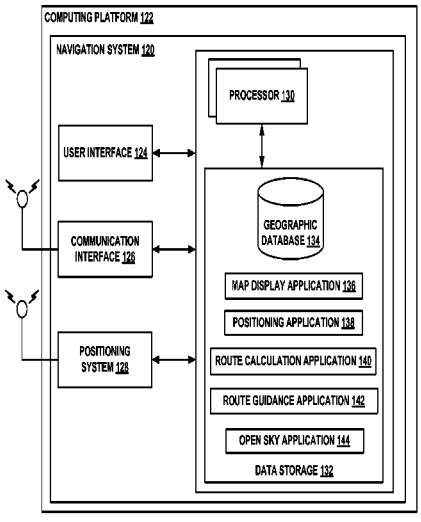
(Continued)

Primary Examiner — Luke Ratcliffe
Assistant Examiner — Vicente Rodriguez
(74) *Attorney, Agent, or Firm* — Lempia Summerfield Katz LLC

(57) **ABSTRACT**

A method and system for generating and using open sky data is described. A vehicle equipped with a range-finding device travels on a road network in a geographic region. The range-finding device transmits a pulse at a given position and obtains range data associated with the position. The system uses the range data to generate data representing visibility of open sky at the given position and at other positions along the road network. For example, the system may determine transmission angles of pulses transmitted at positions that did not encounter a physical object and then use the determined transmission angles to generate data representing visibility of open sky at these positions. The system then stores the data representing the visibility of open sky. The system then associates the data representing the visibility of open sky with data representing physical features.

20 Claims, 9 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2010/0017046 A1 1/2010 Cheung et al.
2010/0020306 A1 1/2010 Hall
2010/0176992 A1* 7/2010 T'siobbel 342/357.25
2011/0153742 A1* 6/2011 Sloop et al. 709/204

OTHER PUBLICATIONS

Xin Chen et al., Toward Next-Generation Map Making, Jun. 28-Jul. 3, 2009, pp. 1676-1683, Multimedia and Expo.

* cited by examiner

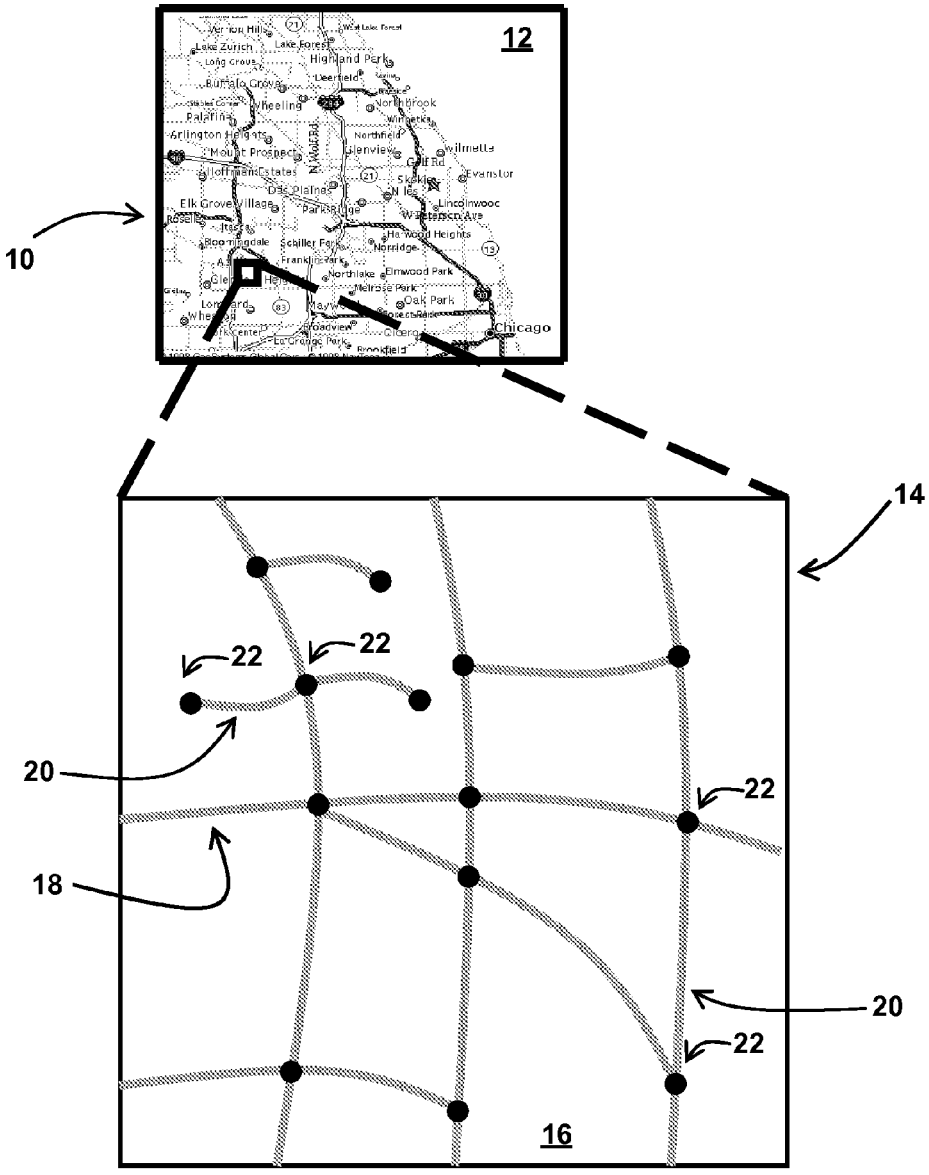


FIG. 1

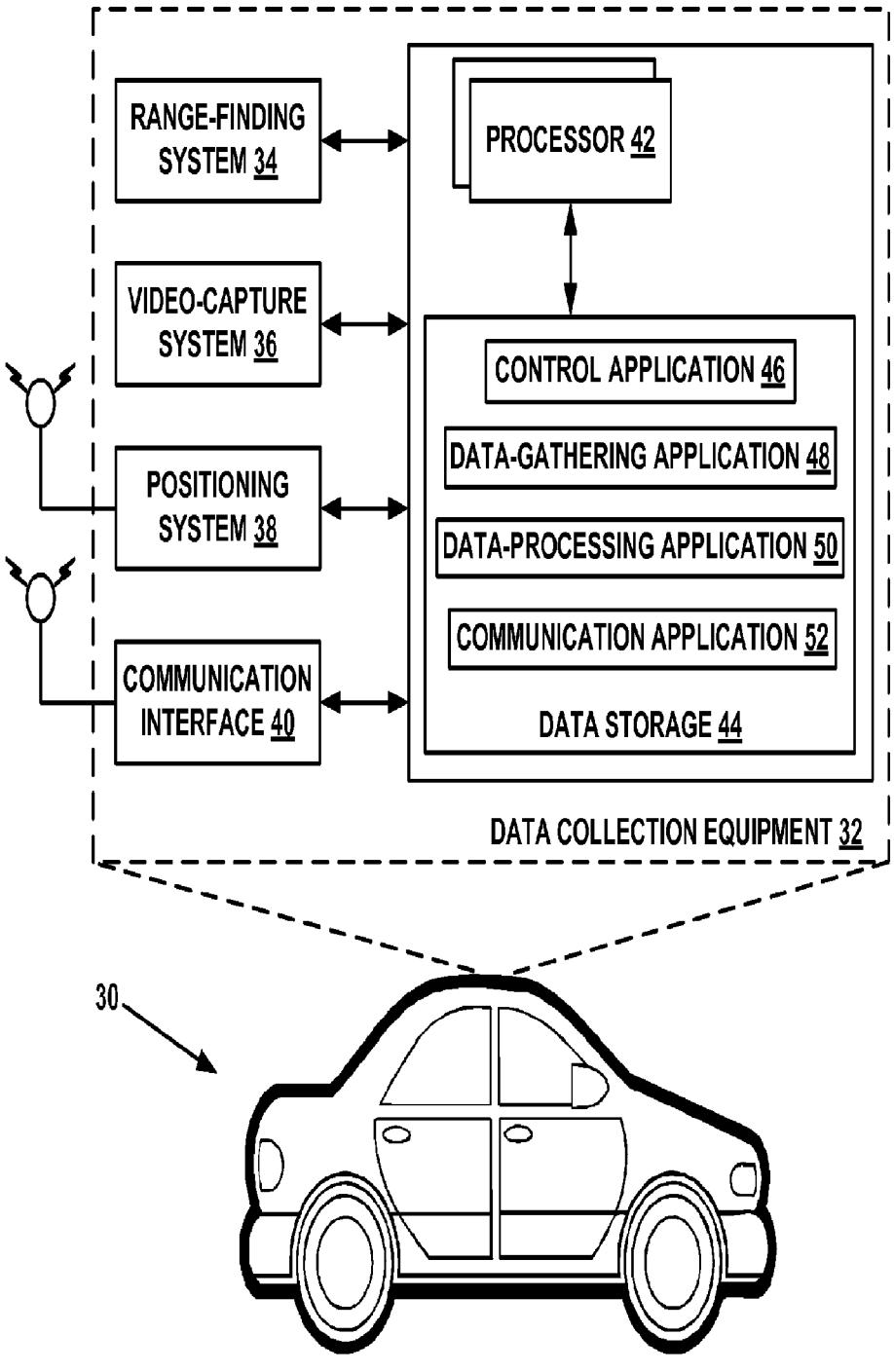

RANGE-FINDING SYSTEM 34
VIDEO-CAPTURE SYSTEM 36
POSITIONING SYSTEM 38
COMMUNICATION INTERFACE 40
PROCESSOR 42
CONTROL APPLICATION 46
DATA-GATHERING APPLICATION 48
DATA-PROCESSING APPLICATION 50
COMMUNICATION APPLICATION 52
DATA STORAGE 44
DATA COLLECTION EQUIPMENT 32
30

FIG. 2

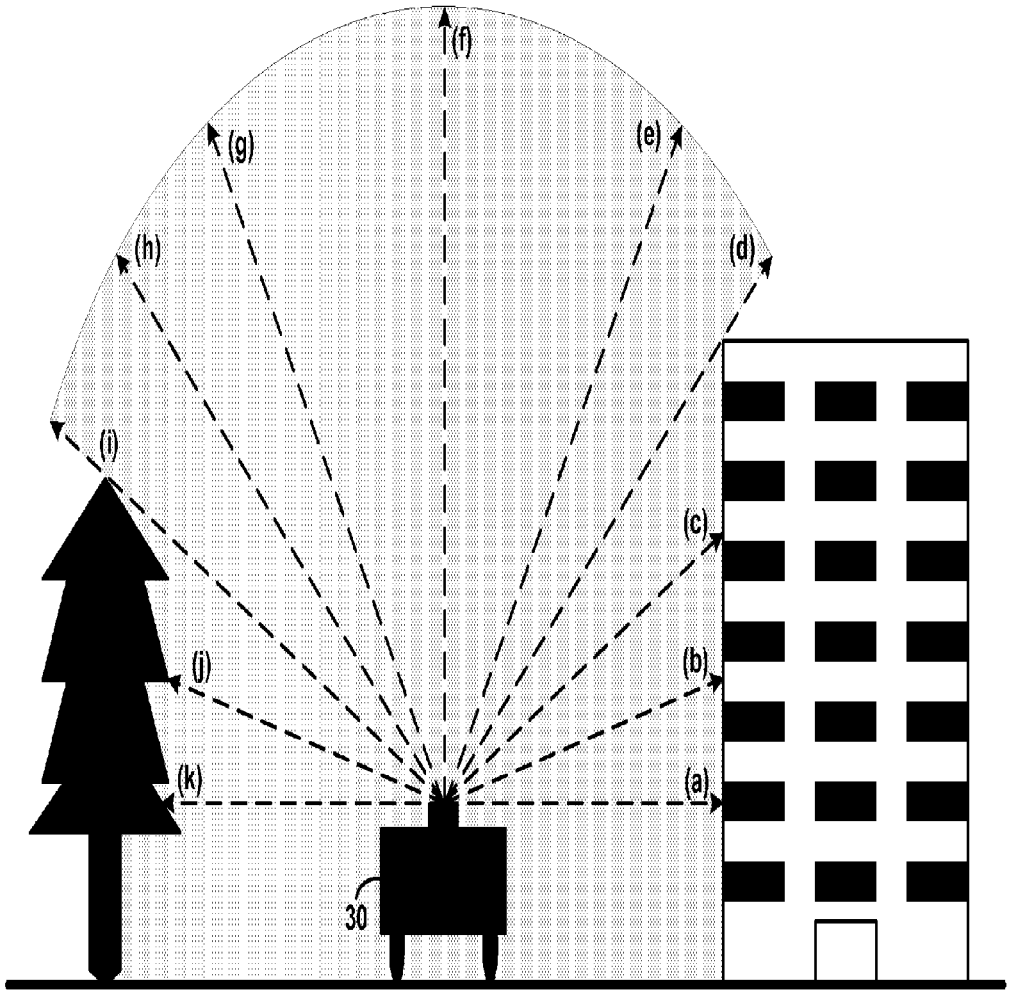


FIG. 3

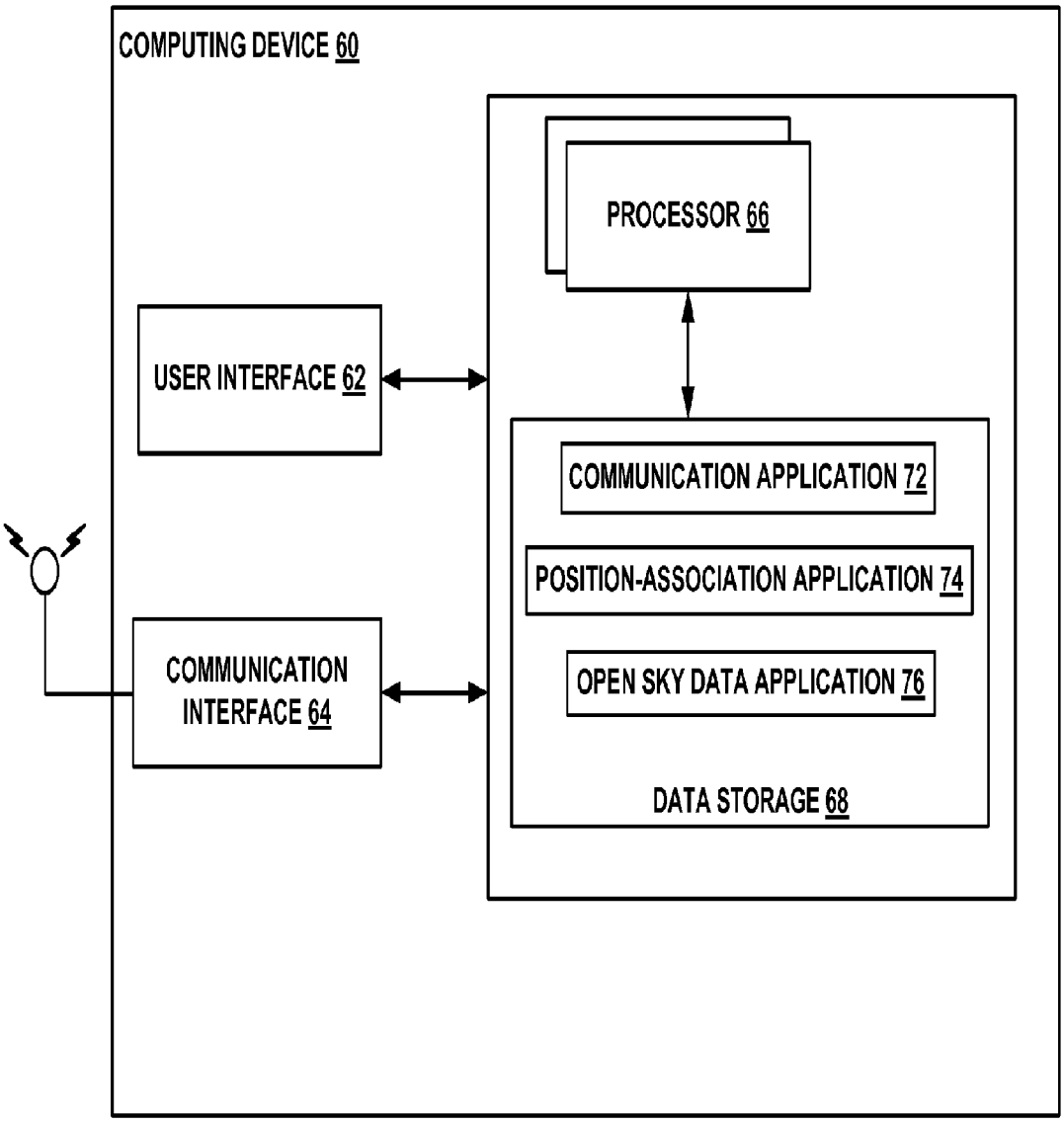

COMPUTING DEVICE 60
PROCESSOR 66
USER INTERFACE 62
COMMUNICATION APPLICATION 72
POSITION-ASSOCIATION APPLICATION 74
OPEN SKY DATA APPLICATION 76
DATA STORAGE 68
COMMUNICATION INTERFACE 64

FIG. 4

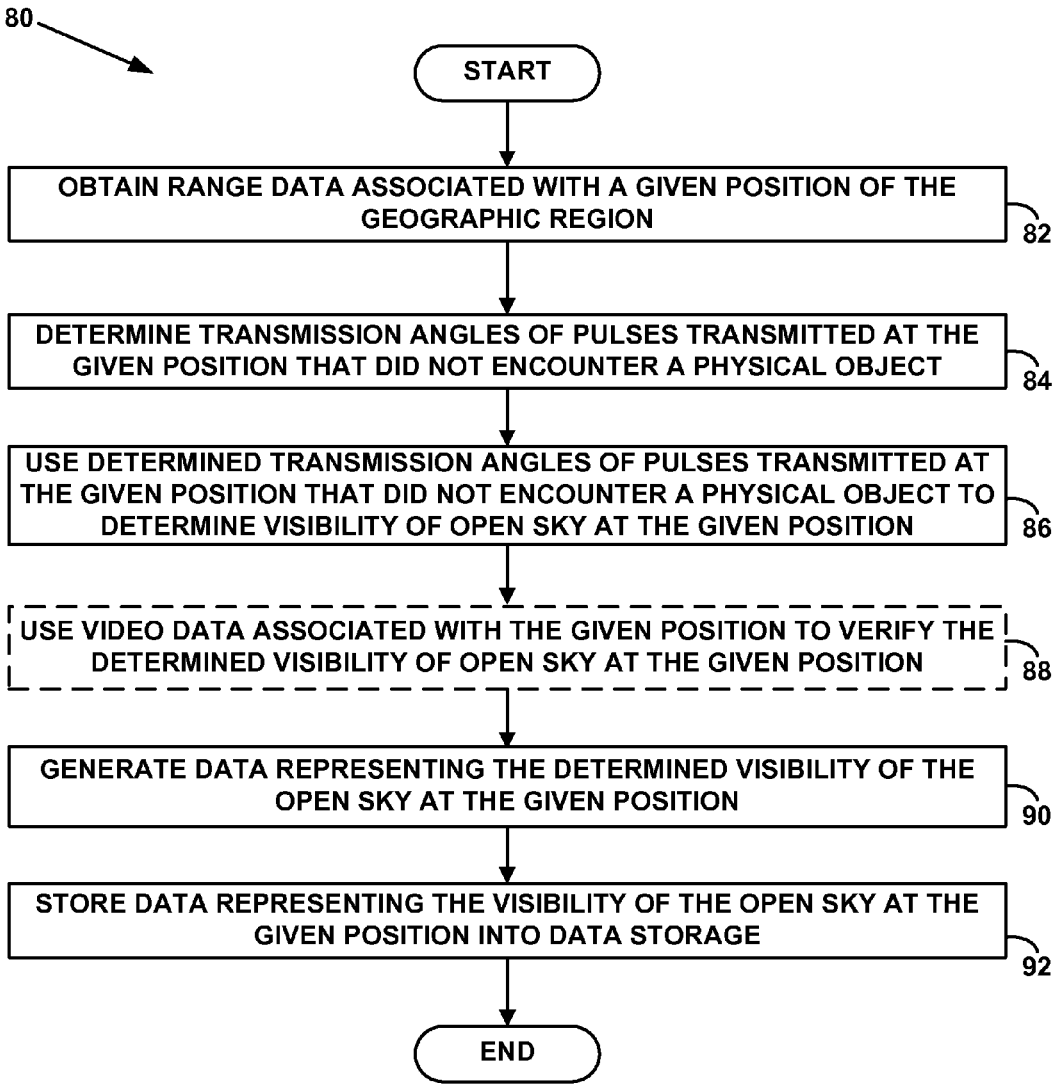

80
START
OBTAIN RANGE DATA ASSOCIATED WITH A GIVEN POSITION OF THE GEOGRAPHIC REGION
82
DETERMINE TRANSMISSION ANGLES OF PULSES TRANSMITTED AT THE GIVEN POSITION THAT DID NOT ENCOUNTER A PHYSICAL OBJECT
84
USE DETERMINED TRANSMISSION ANGLES OF PULSES TRANSMITTED AT THE GIVEN POSITION THAT DID NOT ENCOUNTER A PHYSICAL OBJECT TO DETERMINE VISIBILITY OF OPEN SKY AT THE GIVEN POSITION
86
USE VIDEO DATA ASSOCIATED WITH THE GIVEN POSITION TO VERIFY THE DETERMINED VISIBILITY OF OPEN SKY AT THE GIVEN POSITION
88
GENERATE DATA REPRESENTING THE DETERMINED VISIBILITY OF THE OPEN SKY AT THE GIVEN POSITION
90
STORE DATA REPRESENTING THE VISIBILITY OF THE OPEN SKY AT THE GIVEN POSITION INTO DATA STORAGE
92
END

FIG. 5

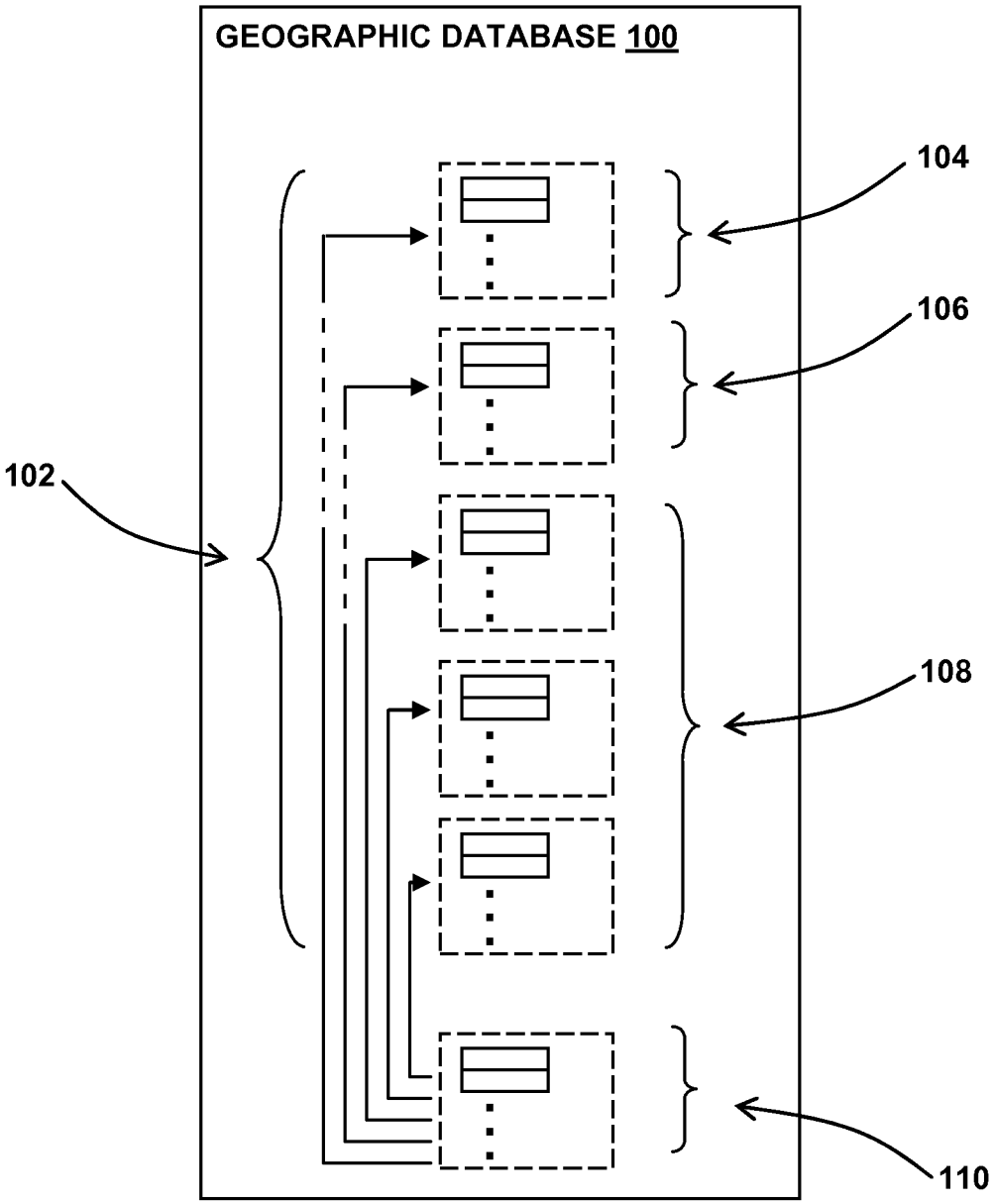


FIG. 6

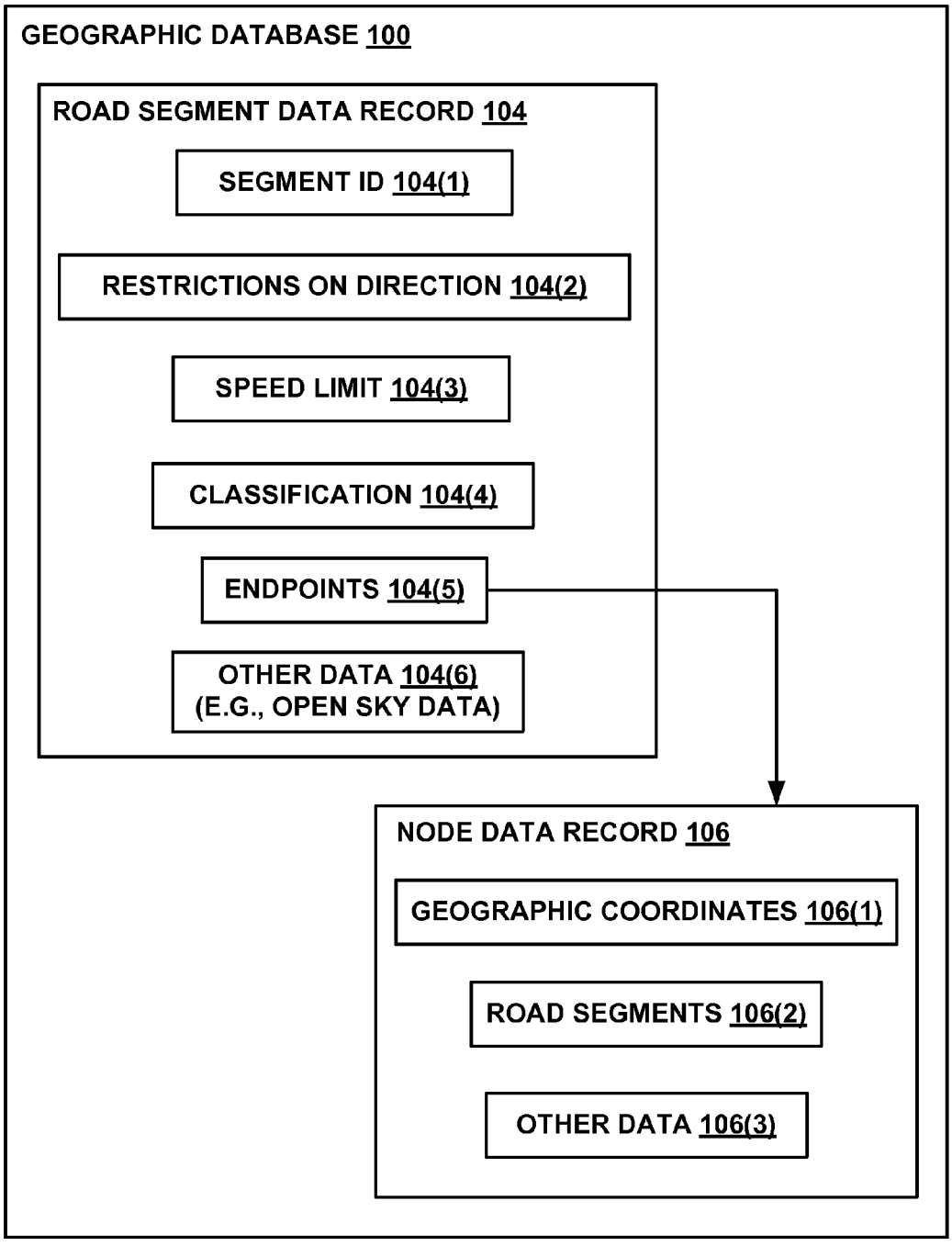

GEOGRAPHIC DATABASE 100
ROAD SEGMENT DATA RECORD 104
SEGMENT ID 104(1)
RESTRICTIONS ON DIRECTION 104(2)
SPEED LIMIT 104(3)
CLASSIFICATION 104(4)
ENDPOINTS 104(5)
OTHER DATA 104(6)
(E.G., OPEN SKY DATA)
NODE DATA RECORD 106
GEOGRAPHIC COORDINATES 106(1)
ROAD SEGMENTS 106(2)
OTHER DATA 106(3)

FIG. 7

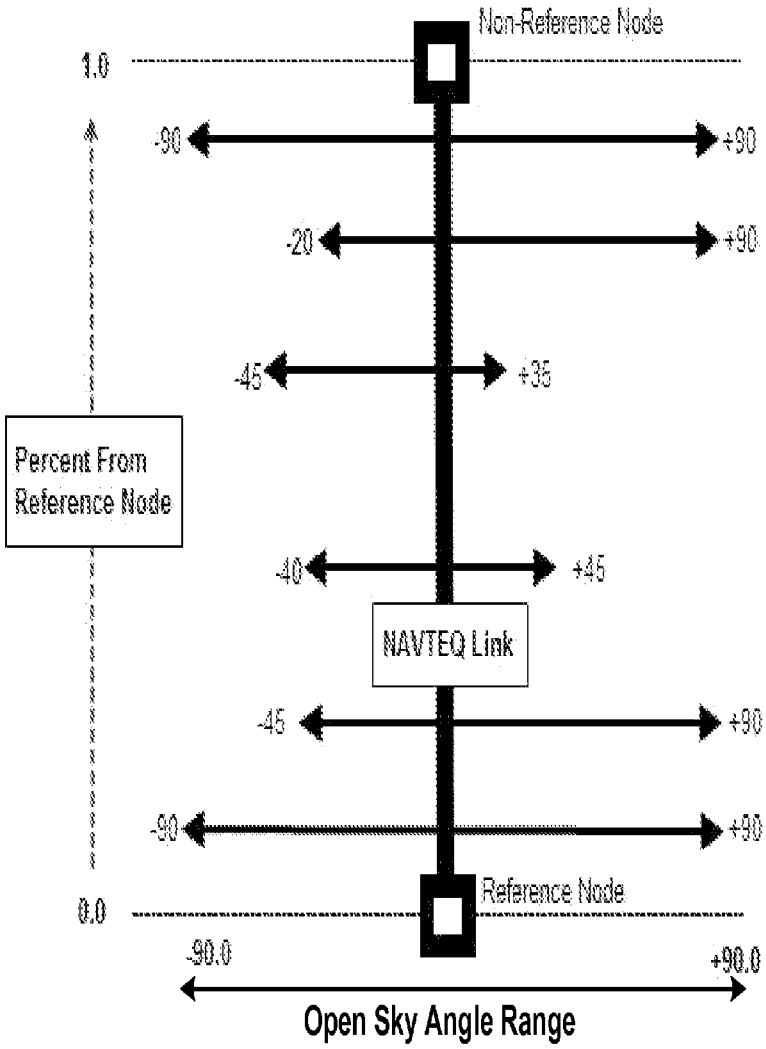

Non-Reference Node
1.0
-90
+90
-20
+90
-45
+35
Percent From Reference Node
-40
+45
NAVTEQ Link
-45
+90
-90
+90
Reference Node
0.0
-90.0
+90.0
Open Sky Angle Range

FIG. 8

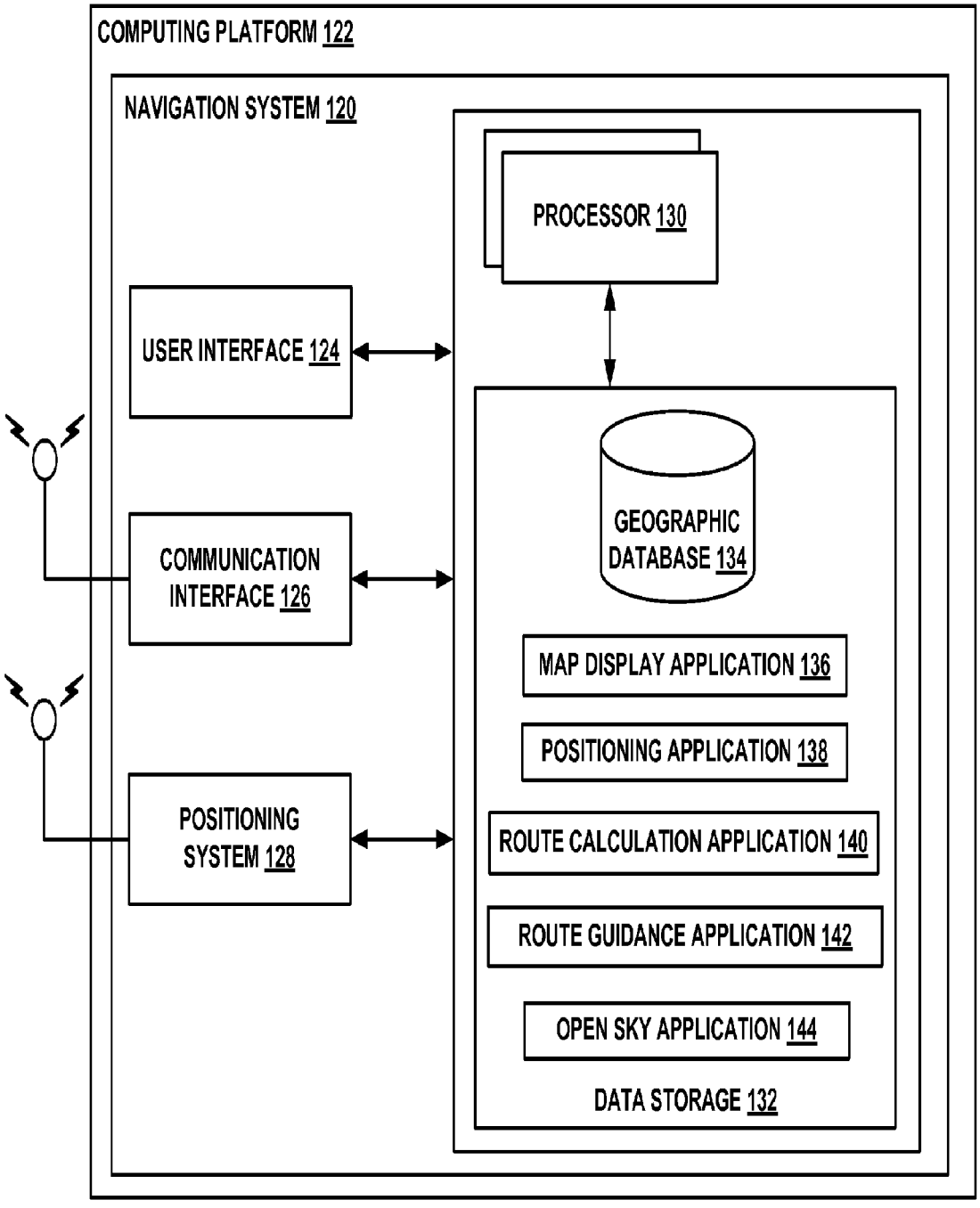

COMPUTING PLATFORM 122
NAVIGATION SYSTEM 120
PROCESSOR 130
USER INTERFACE 124
GEOGRAPHIC DATABASE 134
COMMUNICATION INTERFACE 126
MAP DISPLAY APPLICATION 136
POSITIONING APPLICATION 138
POSITIONING SYSTEM 128
ROUTE CALCULATION APPLICATION 140
ROUTE GUIDANCE APPLICATION 142
OPEN SKY APPLICATION 144
DATA STORAGE 132

FIG. 9

SYSTEM AND METHOD OF GENERATING AND USING OPEN SKY DATA

This application is a divisional application under 37 C.F.R. §1.53(b) and 35 U.S.C. §121 of U.S. patent application Ser. No. 12/756,338 filed Apr. 8, 2010, the disclosure of which is incorporated herein by reference in its entirety

BACKGROUND

Navigation systems are available that provide users with various navigation-related functions and features. For example, some navigation systems are able to determine an optimum route to travel along a road and/or a pedestrian pathway from an origin location to a destination location in a geographic region. Using input from a user, and optionally from equipment that can determine the user's location (such as a global positioning system (GPS)), the navigation system can examine various potential routes between the origin and destination locations to determine the optimum route.

The navigation system may then provide the user with information about the optimum route in the form of guidance that identifies the driving and/or walking maneuvers required to be taken by the user to travel from the origin to the destination location. The guidance may take the form of visual and/or audio instructions that are provided along the way as the user is traveling the route. Some navigation systems are able to show detailed maps on displays outlining the route, the types of maneuvers to be taken at various locations along the route, locations of certain types of features, and so on.

In order to provide these and other navigation-related functions and features, navigation systems use geographic data. The geographic data may be in the form of one or more geographic databases that include data representing physical features in the geographic region. The geographic database includes information about the represented geographic features, such as the positions of the roads, speed limits along portions of roads, address ranges along the road portions, turn restrictions at intersections of roads, direction restrictions, such as one-way streets, and so on. The geographic data may also include information about points of interest, such as restaurants, hotels, airports, gas stations, stadiums, police stations, and so on.

While navigation systems provide useful information to users, there continues to be room for new features and improvements.

SUMMARY

Disclosed herein is a method and system of generating and using open sky data. In one example, a method of generating data representing open sky includes: (a) obtaining range data associated with a given position; (b) using the range data associated with the given position to generate data representing visibility of open sky at the given position; and (c) storing into data storage the data representing the visibility of open sky at the given position. These steps may be repeated for various positions within a geographic region to generate data representing open sky in the geographic region. The data representing open sky in the geographic region may then be used for various purposes, such as to provide users with navigation-related functions and features.

The range data may take various forms. In one example, the range data may include data generated by a light detection and ranging system at the given position. In another example, the range data may include a plurality of data records, each representing attributes of a respective pulse transmitted by a range-finding device at the given position. In this respect, the attributes of the respective pulse may include a transmission angle of the pulse and a distance of a physical object encountered by the pulse. Other examples are possible as well.

The step of using the range data associated with the given position to generate data representing visibility of open sky at the given position may also take various forms. In one example, this step may include: (1) analyzing the obtained range data to determine transmission angles of pulses transmitted at the given position that did not encounter a physical object; (2) using the determined transmission angles of the pulses transmitted at the given position that did not encounter a physical object to determine visibility of open sky at the given position; and (3) generating data representing the determined visibility of the open sky at the given position. Additionally, before generating data representing the determined visibility of the open sky at the given position, this step may include using video data associated with the given position to verify the determined visibility of open sky at the given position. Other examples are possible as well.

The step of analyzing the obtained range data to determine transmission angles of pulses transmitted at the given position that did not encounter a physical object may also take various forms. In one example, this step may include: (1) for a given pulse transmitted at the given position, analyzing a data value indicating a distance of a physical object encountered by the given pulse; and (2) if the data value is a null, identifying a transmission angle of the given pulse as a transmission angle of a pulse that did not encounter a physical object. In another example, this step may include: (1) analyzing the obtained range data to identify gaps in the transmission angles of pulses transmitted at the given position that encountered a physical object; and (2) identifying transmission angles within the identified gaps as transmission angles of pulses that did not encounter a physical object. Other examples are possible as well.

The data representing the visibility of open sky at the given position may take various forms. In one example, this data may include data indicating each angle at which the open sky is visible from the given position. In anther example, this data may include data indicating one or more ranges of angles at which the open sky is visible from the given position. In yet another example, this data may include data indicating a distance of a physical object at each edge of each range of angles. In still another example, this data may include data indicating a visibility rating for each range of angles. Other examples are possible as well.

The step of storing into data storage the data representing the visibility of open sky at the given position may also take various forms. In one example, this step may include associating the data representing the visibility of open sky at the given position with data representing physical features (e.g., a road network) at the given position. In another example, this step may include storing into data storage the data representing the visibility of open sky at the given position only if the data representing the visibility of open sky at the given position indicates a significant change in the visibility of open sky from a previous position. Other examples are possible as well.

The method of generating data representing open sky may also include other features. In one example, the method may additionally include selecting the given position based on data representing a road network of a geographic region before obtaining range data associated with the given position. In another example, the method may additionally include providing the data representing the visibility of open sky at the given position to a navigation system.

In another aspect, a system may include a processor, data storage, and open sky data entities stored in the data storage and accessible by the processor, where each open sky data entity represents visibility of open sky at a respective position. Additionally, the system may include road-network data entities stored in the data storage and accessible by the processor, where each road-network data entity represents a road network at a respective position, and where the open sky data entities and the road-network data entities are associated based on position. Additionally yet, the system may include program instructions stored in the data storage and executable by the processor for using the open sky data entities to perform various functions, such as to determine an availability of GPS signals at one or more positions, an availability of radio signals at one or more positions, and/or exposure to weather conditions at one or more positions.

In yet another aspect, a tangible computer readable medium may have data stored thereon including: (1) open sky data entities each representing visibility of open sky at a respective position; and (2) geographic data entities each representing a geographic feature at a respective position, where the open sky data entities and the geographic data entities are associated based on position.

These as well as other aspects and advantages will become apparent to those of ordinary skill in the art by reading the following detailed description, with reference where appropriate to the accompanying drawings. Further, it is understood that this summary is merely an example and is not intended to limit the scope of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a map of a geographic region;

FIG. **2** shows a vehicle with data collection equipment that is capable of collecting data about the geographic region of FIG. **1**, according to an example embodiment;

FIG. **3** is rear view of a light detection and ranging system operating in the vehicle of FIG. **2**;

FIG. **4** is a block diagram of a computing device configured to generate geographic data, according to an example embodiment;

FIG. **5** is a flow chart depicting a method of generating open sky data, according to an example embodiment;

FIG. **6** depicts a geographic database, according to an example embodiment;

FIG. **7** shows some of the components of a road segment data record and a node data record contained in the geographic database of FIG. **5**, according to an example embodiment;

FIG. **8** is a visual representation of stored open sky data for a road segment, according to an example embodiment; and

FIG. **9** is a block diagram of a navigation system, according to an example embodiment.

DETAILED DESCRIPTION

The example embodiments described herein may determine and generate data representing the visibility of the open (i.e., unblocked or partially blocked) sky from various positions on the earth, such as positions on roads or pedestrian pathways or at points of interest. In this respect, the example embodiments may define not only the visibility of the open sky straight above a position, but also the visibility of the open sky (and, thus, the horizon) at all angles from the position. The example embodiments may also use the data representing the visibility of the open sky for various purposes, such as to determine GPS satellite reception, radio reception, and/or exposure to weather conditions (e.g., exposure to sun, rain, or snow) at various positions.

It should be understood that the arrangements described herein are set forth for purposes of example only. As such, those skilled in the art will appreciate that other arrangements and other elements (e.g., components, interfaces, functions, orders of functions, etc.) can be used instead, some elements may be added, and/or some elements may be omitted altogether. Further, those skilled in the art will appreciate that many of the elements described herein are functional elements that may be implemented as discrete or distributed components or in conjunction with other components, and in any suitable combination and location. Still further, various functions described herein as being performed by one or more entities may be carried out by hardware, firmware, and/or software. For instance, various functions may be carried out by a processor executing a set of program instructions written in any suitable programming language (e.g., C, C++, Java, etc.) and stored in memory.

I. Data Collection

FIG. **1** shows a map **10** of a geographic region **12**. The geographic region **12** may correspond to a metropolitan or rural area, a state, a country, or combinations thereof, or any other area of comparable size. Located in the geographic region **12** are physical features, such as roads, points of interest (including businesses, facilities, etc.), pedestrian pathways (e.g., sidewalks, bike paths, etc.), lakes, rivers, railroads, and so on.

FIG. **1** also includes an enlarged map **14** of a portion **16** of the geographic region **12**. The enlarged map **14** illustrates part of the road network **18** in the geographic region **12**. The road network **18** includes, among other things, roads and intersections located in the geographic region **12**. As shown in the portion **16**, each road in the geographic region **12** is composed of one or more road segments **20**. A road segment **20** represents a portion of the road. Each road segment **20** is shown to have associated with it two nodes **22**; one node represents the point at one end of the road segment and the other node represents the point at the other end of the road segment. The node **22** at either end of a road segment may correspond to a location at which the road meets another road, i.e., an intersection, or where the road dead-ends.

In order to provide navigation-related functions and features in the geographic region **12**, a party (e.g., a map developer) may first collect data about the geographic region **12**. In this respect, the party may use vehicles traveling along the road network **18** of the geographic region **12** to collect data about the geographic region **12**. It should be understood, however, that the party may additionally or alternatively employ other systems and methods to collect data about the geographic region **12** (e.g., data collection equipment affixed to a tripod or carried by pedestrians, vehicles traveling on pedestrian pathways, etc.) that are within the scope of the example embodiments described herein.

FIG. **2** shows a vehicle **30** with data collection equipment **32** that is capable of collecting data about the geographic region **12**, according to an example embodiment. As shown, the data collection equipment **32** includes a range-finding system **34**, an image-capture system **36**, a positioning system **38**, and a communication interface **40**, each operatively coupled to a processor **42** and data storage **44**. The data collection equipment **32** may include other components as well. The components of the data collection equipment **32** may be arranged in various manners. In one aspect, components may be physically separate from one another, in which case the components may be linked together via a system bus,

network, or other connection mechanism. In another aspect, components may be physically integrated together in whole or in part. Many other configurations are possible as well.

The range-finding system **34** may function to scan and generate range data representing an area surrounding the vehicle's position. In this respect, the range-finding system **34** may continuously generate range data as the vehicle **30** travels along the road network **18**. The range-finding system **34** and range data may take various forms.

In one embodiment, the range-finding system **34** may take the form of a light detection and ranging (LIDAR) system that uses laser pulses to scan the area surrounding the vehicle's position, such as a HDL-**64**E system manufactured by Velodyne Lidar Inc. or an LMS2xx system manufactured by SICK AG. The LIDAR system may transmit laser pulses radially in various directions from a reference point on the range-finding system **34**. For example, the LIDAR system may transmit laser pulses at a nearly continuous range of angles (e.g., every 0.1°) in one or more two-dimensional spaces (e.g., planes). In this respect, the LIDAR system may include a bank of laser transmitters (e.g., 64 transmitters) that continuously rotates around the reference point (e.g., at a rate of 10 rotations per second). During a rotation, each laser transmitter in the bank may transmit a plurality of laser pulses in a respective planar space, with each laser pulse having a respective angle about the LIDAR rotation axis. Each laser pulse transmitted by the LIDAR system may also have a non-planar, three-dimensional, conic transmission angle with the laser transmitter tilted relative to the LIDAR rotation axis. Other examples are possible as well.

FIG. **3** is rear view of an example LIDAR system operating in the vehicle **30** as it is positioned on a road with a tree on a left side and a building on a right side. As shown, the example LIDAR system may transmit laser pulses at a nearly continuous range of angles in a plane perpendicular to the travel direction of the vehicle **30**. For purposes of illustration,

FIG. **3** also highlights example laser pulses (a)-(k), which the example LIDAR system transmits at angles of 90°, 75°, 60°, 45°, 30°, 0, −30°, −45°, −60°, −75°, and −90° respectively.

For each laser pulse transmitted by a given laser transmitter, the LIDAR system may then monitor whether the laser pulse is reflected back to the LIDAR system by a physical object within range of the LIDAR system. In this respect, if the LIDAR system detects a reflection of the laser pulse, the LIDAR system may measure attributes of the laser pulse's reflection, such as a time between transmission of the laser pulse and detection of the reflection and/or an intensity of the reflection. Based on the time measurement, the LIDAR system may also calculate a distance (typically within a few centimeters) of an encountered physical object relative to the reference point. If the LIDAR system does not detect a reflection of the laser pulse, however, the LIDAR system may consider all attributes of the laser pulse's reflection to be null (e.g., 0). For example, with reference to FIG. **3**, the example LIDAR system may calculate the distance of the building encountered by example laser pulses (a)-(c) as 10 meters, 10.7 meters, and 13.5 meters respectively, the distance of the tree encountered by the example laser pulses (j)-(k) as 10.3 meters and 10.5 meters respectively, and the distance of a physical object encountered by the laser pulses (d)-(i) as 0 meters.

After monitoring for and determining attributes of the laser pulse's reflection, the LIDAR system may generate range data representing attributes of the laser pulse. For example, the LIDAR system may generate a data record (or "entity" or "entry") for the laser pulse that includes data indicating an identity of the laser transmitter from which the laser pulse originated, a rotation angle of the laser transmitter during transmission of the laser pulse, a distance of a physical object encountered by the laser pulse (if any), and/or an intensity of the laser pulse's reflection (if any). Other examples are possible as well.

From each position of the vehicle **30**, the LIDAR system may transmit and generate range data for a plurality of laser pulses with respective transmission angles relative to the LIDAR system. This range data, which represents an area surrounding the vehicle **30**, may then be processed along with other data (e.g., position data for the vehicle **30**, etc.) to generate geographic data representing the geographic region **12**. For example, a party may process range data indicating physical features surrounding the vehicle **30** (e.g., range data records that include a non-null distance value) to generate geographic data representing physical features at various positions in the geographic region **12**. As another example, as discussed below, a party may process range data indicating a lack of physical features surrounding the vehicle **30** (e.g., range data records that include a null distance value) to generate geographic data representing the visibility of the open sky at various positions in the geographic region **12**. Other examples are possible as well.

The video-capture system **36** may function to capture and generate video data representing an area surrounding the vehicle **30**. In this respect, the video-capture system **36** may continuously generate video data as the vehicle **30** travels along the road network **18**. The video-capture system **36** and the video data may take various forms. In one embodiment, the video-capture system **36** may take the form of a video camera with multiple lenses of various orientations that is capable of capturing the area surrounding the vehicle **30** in all directions, such as a Ladybug®3 spherical digital video camera manufactured by Point Grey Research, Inc. In this respect, the video data may take the form of 360° panoramic video frames. As discussed below, a party may use the video data during processing of the range data to generate geographic data representing the visibility of the open sky at various positions in the geographic region **12**.

The positioning system **38** may function to track and generate position data representing a position of the vehicle **30**. (It should be understood, however, that the position data for the vehicle may alternatively be derived from the range data and/or the video data). In this respect, the positioning system **38** may continuously generate position data as the vehicle **30** travels along the road network **18**. The positioning system **38** may employ any technology now known or later developed, including GPS-type technology, dead reckoning-type technology, or a combination of these or other technologies, all of which are known in the art. Further, the positioning system **38** may include various components, including a GPS receiver, an inertial measurement unit (IMU), wheel-rotation sensors, steering-direction sensors, and/or any other device that enables tracking of the vehicle's position. Further yet, the position data may take various forms, including data indicating geographic coordinates (latitude, longitude, and altitude), direction, orientation, and/or speed of the vehicle **30** for instance. In one example, the positioning system **38** may be part of an IP-S2 system manufactured by Topcon Positioning Systems, Inc. As discussed below, a party may use the position data during processing of the range data to generate geographic data representing the visibility of the open sky at various positions in the geographic region **12**.

The communication interface **40** may function to communicatively couple the data collection equipment **32** to one or more other devices. In this respect, the communication inter-

face **40** may take the form of one or more interfaces that provide for wireless and/or wired communication with another device, such as an Ethernet interface, a serial bus interfaces (e.g., Firewire, USB 2.0, etc.), a chipset and antenna adapted to facilitate wireless communication according a desired protocol, or any other such interfaces now known or later developed. Other configurations are also possible.

The processor **42** may function to execute or interpret program instructions (which may be arranged into an application) that enable the processor **42** to carry out various tasks, such as tasks related to the collection of data about the geographic region **12** for instance. In this respect, the processor **42** may take the form of one or more processor components, such as general-purpose processors (e.g., a microprocessor), application-specific processors (e.g., an application-specific integrated circuit (ASIC) or digital signal processor (DSP)), programmable logic devices (e.g., a field programmable gate array (FPGA)), or other processor components now known or later developed. Other configurations are possible as well.

The data storage **44** may function to store various types of program instructions and data that can be read by the processor **42**, such as applications and data generated by the range-finding system **34**, the video-capture system **36**, and the positioning system **38**, for instance. In this respect, the data storage **44** may take the form of one or more data storage mediums, such as volatile data storage mediums (e.g., random access memory (RAM), registers, and/or cache) and/or non-volatile data storage mediums (e.g., read only memory (ROM), a hard disk drive, a solid state drive, flash memory, an optical storage device, and/or a floppy disk). Some data storage mediums may be integrated in whole or in part with the processor **42**. Further, some data storage mediums may be external to and/or removable from the data collection equipment **32**, and may interface with the data collection equipment **32** in various manners (e.g., via the communication interface **40**, a drive, or a reader). Other configurations are possible as well.

The data storage **44** may contain one or more applications that enable the processor **42** to perform various tasks related to the collection of data about the geographic region **12**. The one or more applications may be stored in various components of the data storage **44**. For example, the one or more applications may be stored in a non-volatile data storage medium (e.g., a hard disk drive or a removable storage component installed in a drive) and then loaded into a volatile data storage medium (e.g., RAM) when operated on by the processor **42**. Other examples are possible as well. In one embodiment, the one or more applications may be stored in a different data storage medium from the data generated by the range-finding system **34**, the video-capture system **36**, and the positioning system **38**.

In one aspect, the data storage **44** may contain a control application **46** that enables the processor **42** to control the range-finding system **34**, the video-capture system **36**, and/or the positioning system **38**. For example, the processor **42** executing the control application **46** may initiate and cease data collection by the range-finding system **34**, the video-capture system **36**, and/or the positioning system **38**. As another example, the processor **42** executing the control application **46** may adjust collection settings (e.g., collection rate) for the range-finding system **34**, the video-capture system **36**, and/or the positioning system **38**. Other examples are possible as well.

In another aspect, the data storage **44** may contain a data-gathering application **48** that enables the processor **42** to obtain and store data from the range-finding system **34**, the video-capture system **36**, and/or the positioning system **38**. For example, the processor **42** executing the data-gathering application **48** may receive data from the range-finding system **34**, the video-capture system **36**, and/or the positioning system **38**. As another example, the processor **42** executing the data-gathering application **48** may store data from the range-finding system **34**, the video-capture system **36**, and/or the positioning system **38** (in either processed or unprocessed form) into the data storage **44**. Other examples are possible as well.

In yet another aspect, the data storage **44** may contain a data-processing application **50** that enables the processor **42** to process data obtained from the range-finding system **34**, the video-capture system **36**, and/or the positioning system **38**. For example, the processor **42** executing the data-processing application **50** may associate data generated by the range-finding system **34**, the video-capture system **36**, and/or the positioning system **38** by applying capture timestamps to that data. In another example, the processor **42** executing the data-processing application **50** may organize data obtained from the range-finding system **34**, the video-capture system **36**, and/or the positioning system **38** for storage and/or transmission. Other examples are possible as well.

In a further aspect, the data storage **44** may contain a communication application **52** that enables the processor **42** to communicate with other devices via the communication interface **40**. In one example, the processor **42** executing the communication application **52** may receive messages from another device via the communications interface **40**, such as messages that request range data, video data, and/or position data. In another example, the processor **42** executing the communication application **52** may send messages to another device via the communications interface **40**, such as messages that include range data, video data, and/or position data (in either processed or unprocessed form). Other examples are possible as well.

II. Generation of Geographic Data

Using the vehicle **30** described above (and/or another system), a party may collect range data, video data, and position data for at least a portion of the geographic region **12**. Once that collection is complete, a party (e.g., the collecting party or another party) may use the collected data to generate geographic data, potentially for incorporation into a geographic database and/or use by a navigation system. In this respect, the party may generate the geographic data on a computing device, such as a personal computer or a server computer.

FIG. **4** is a block diagram of a computing device **60** configured to generate geographic data, according to an example embodiment. As shown, the computing device **60** may include a user interface **62** and a communication interface **64**, each operatively coupled to a processor **66** and data storage **68**. The computing device **60** may include other components as well.

The user interface **62** may function to facilitate user interaction with the computing device **60**, such as by allowing a user to input information into the computing device **60** and obtain information from the computing device **60**. In this respect, the user interface **62** may include or provide connectivity to various input components, such as a keyboard, a mouse, and/or a microphone for instance. The user interface **62** may also include or provide connectivity to various output components, such as a display screen and/or a speaker for instance. The user interface **62** may include or provide connectivity to other components for facilitating user interaction with the computing device **60** as well.

The communication interface **64** may function to communicatively couple the computing device **60** to one or more

other devices, such as the data collection equipment **32** and/or one or more navigation systems for instance. In this respect, the communication interface **64** may take the form of one or more interfaces that provide for wireless and/or wired communication with another device, such as an Ethernet interface, a serial bus interfaces (e.g., Firewire, USB 2.0, etc.), a chipset and antenna adapted to facilitate wireless communication according a desired protocol, or any other such interfaces now known or later developed. Other configurations are also possible.

The processor **66** may function to execute or interpret program instructions (which may be arranged into an application) that enable the processor **66** to carry out various tasks, such as tasks related to generating geographic data for instance. In this respect, the processor **66** may take the form of one or more processor components, such as general-purpose processors (e.g., a microprocessor), application-specific processors (e.g., an ASIC or DSP), programmable logic devices (e.g., a FPGA), or other processor components now known or later developed. Other configurations are possible as well.

The data storage **68** may function to store various types of program instructions and data that can be read by the processor **66**, such as applications, data received from the data collection equipment **32**, and geographic data, for instance. In this respect, the data storage **68** may take the form of one or more data storage mediums, such as volatile data storage mediums (e.g., RAM, registers, and/or cache) and/or non-volatile data storage mediums (e.g., ROM, a hard disk drive, a solid state drive, flash memory, an optical storage device, and/or a floppy disk). Some data storage mediums may be integrated in whole or in part with the processor **66**. Further, some data storage mediums may be external to and/or removable from the computing device **60**, and may interface with the computing device **60** in various manners (e.g., via the communication interface **64**, a drive, or a reader). Other configurations are possible as well.

The data storage **68** may contain one or more applications that enable the processor **66** to perform various tasks related to generating geographic data. The one or more applications may be stored in various components of the data storage **68**. For example, the one or more navigation applications may be stored in a non-volatile data storage medium (e.g., a hard disk drive or a removable storage component installed in a drive) and then loaded into a volatile data storage medium (e.g., RAM) when operated on by the processor **66**. Other examples are possible as well.

In one aspect, the data storage **68** may contain a communication application **72** that enables the processor **66** to communicate with other devices via the communication interface **64**. In one example, the processor **66** executing the communication application **72** may receive messages from another device via the communications interface **64**, such as messages from the data collection equipment **32** that include range data, video data, and position data or messages from navigation systems that request geographic data. In another example, the processor **66** executing the communication application **72** may send messages to another device via the communications interface **64**, such as messages to the data collection equipment **32** that request range data, video data, and position data or messages to navigation systems that include geographic data. Other examples are possible as well.

In another aspect, the data storage **68** may contain a position-association application **74** that enables the processor **66** to associate range data and video data received from the data collection equipment **32** with respective positions where the data collection equipment **32** collected that data. The processor **66** executing the position-association application **74** may perform the association in various ways. In one example, the processor **66** executing the position-association application **74** may first correlate the range data and video data with the position data, such as by using capture timestamps or sequencing and collection rates of the data. Thereafter, the processor **66** executing the position-association application **74** may use the position data and perhaps other data to determine the respective positions with which to associate the range data and video. Other examples are possible as well. As a result of the processor **66** executing the position-association application **74**, each range data record and video data record may include or link to a position identifier (e.g., geographic coordinates and perhaps orientation).

The position-association application **74** may also enable the processor **66** to transform the range data from a local coordinate system relative to the range-finding system **34** to a world coordinate system. The processor **66** executing the position-association application **74** may perform the transformation in various manners. In one example, the processor **66** executing the position-association application **74** may first determine the three-dimensional transmission angle of each laser pulse relative to the range-finding system **34** based on a static orientation of the originating laser transmitter and a rotation angle of the originating laser transmitter during transmission of the laser pulse. The processor **66** executing the position-association application **74** may then determine the three-dimensional transmission angle of the laser pulse in the world coordinate system based on the three-dimensional transmission angle of the laser pulse relative to the range-finding system **34**, the orientation of the range-finding system **34** relative to the positioning system **38**, and the orientation of the positioning system **38** in world coordinates as indicated by the associated position data. Other examples are possible as well.

In yet another aspect, the data storage **68** may contain an open sky data application **76** that enables the processor **66** to generate and store data representing open sky in the geographical area **12**. The processor **66** executing the open sky data application **76** may perform the open sky data generation in various ways.

FIG. **5** is a flow chart depicting a method **80** of generating open sky data, according to an example embodiment. For purposes of illustration, the following description will assume that the processor **66** carries out the method **80** while executing the open sky data application **76**. Further, the following description will assume that the computing device **60** and/or another device (e.g., the data collection equipment **32**) have previously performed position-association on the data collected by the data collection equipment **32**.

At block **82**, the processor **66** executing the open sky data application **76** may first obtain range data associated with a given position of the geographic region **12**, such as by accessing the data storage **68** and/or receiving the range data from the data collection equipment **32** via the communication interface **64**. For example, the processor **66** executing the open sky data application **76** may obtain range data associated with the position of the vehicle **30** in FIG. **3**. The obtained range data may include multiple range data records (or "entities" or "entries"), each representing attributes of a respective pulse transmitted by the range-finding device **34** at the given position. In turn, each range data record may include at least data values indicating an orientation of the pulse and a distance of a physical object encountered by the pulse (if any) relative to a reference point.

In one example, the obtained range data may include all range data records associated with the given position. In another example, the obtained range data may include only

range data records associated with the given position that include null distance values, or only range data records associated with the given position that include non-null distance values. In either case, because the range-finding system's transmitters may have rotated multiple times while at the given position, the obtained range data may include range data records for a plurality of pulses having the same transmission angle. Other examples are possible as well.

At block **84**, the processor **66** executing the open sky data application **76** may determine the transmission angles at which pulses transmitted from the given position did not encounter a physical object. The processor **66** executing the open sky data application **76** may perform this determination in various manners.

In one aspect, the processor **66** executing the open sky data application **76** may perform this determination based on the obtained range data for pulses transmitted at the given position that did not encounter a physical object. In this respect, if necessary, the processor **66** executing the open sky data application **76** may first analyze the obtained range data to identify pulses transmitted at the given position that did not encounter a physical object. For example, the processor **66** executing the open sky data application **76** may: (a) analyze the data value indicating a distance of a physical object encountered by each pulse transmitted at the given position; and (b) if this data value is a null (e.g., 0), identify the pulse as one that did not encounter a physical object. Other examples are possible as well.

The processor **66** executing the open sky data application **76** may then determine transmission angles of the pulses transmitted at the given position that did not encounter a physical object. For example, the processor **66** executing the open sky data application **76** may access the data value indicating the transmission angle of each pulse transmitted at the given position that did not encounter a physical object. Other examples are possible as well. With reference to FIG. **3**, the processor **66** executing the open sky data application **76** may determine that pulses (d)-(i) with angles of 45°, 30°, 0°, −30°, −45°, and −60° respectively within a plane perpendicular to the travel direction of the vehicle **30** did not encounter a physical object.

In another aspect, the processor **66** executing the open sky data application **76** may perform this determination based on the obtained range data for pulses transmitted at the given position that encountered a physical object. In this respect, if necessary, the processor **66** executing the open sky data application **76** may first analyze the obtained range data to identify pulses transmitted at the given position that encountered a physical object. For example, the processor **66** executing the open sky data application **76** may: (a) analyze the data value indicating a distance of a physical object encountered by each pulse transmitted at the given position; and (b) if this data value is anything other than a null, identify the pulse as one that encountered a physical object. Other examples are possible as well.

The processor **66** executing the open sky data application **76** may then analyze the obtained range data for the pulses transmitted at the given position that encountered a physical object, to identify gaps in the transmission angles of these pulses. In turn, the processor **66** executing the open sky data application **76** may determine that the transmission angles within the identified gaps are transmission angles of pulses transmitted at the given position that did not encounter a physical object. The processor **66** executing the open sky data application **76** may perform this determination in other manners as well.

In yet another aspect, the processor **66** executing the open sky data application **76** may perform this determination based on both the obtained range data for pulses transmitted at the given position that did not encounter a physical object and the obtained range data for pulses transmitted at the given position that encountered a physical object. In this respect, the processor **66** executing the open sky data application **76** may first organize the range data based on transmission angle, such that the obtained range data associated with each represented transmission angle is grouped together. The processor **66** executing the open sky data application **76** may then analyze the obtained range data for each represented transmission angle, to determine a number of pulses having a transmission angle that did not encounter a physical object and a number of pulses having transmission angle that encountered a physical object. Based on this analysis, the processor **66** executing the open sky data application **76** may determine whether the transmission angles are ones at which none, some, or all pulses encountered a physical object.

For example, the processor **66** executing the open sky data application **76** may identify a transmission angle at which 75% or more of pulses did not encounter a physical object as one at which pulses did not encounter a physical object. As another example, the processor **66** executing the open sky data application **76** may identify a transmission angle at which 75% or more of pulses encountered a physical object as one at which pulses encountered a physical object. As still another example, the processor **66** executing the open sky data application **76** may identify a transmission angle at which 25-75% of pulses encountered a physical object as one at which pulses occasionally encountered a physical object.

At block **86**, the processor **66** executing the open sky data application **76** may use the determined transmission angles of the pulses that did not encounter a physical object (and perhaps the determined transmission angles of the pulses that occasionally encountered a physical object) to determine visibility of open sky at the given position. In one aspect, the processor **66** executing the open sky data application **76** may determine that each transmission angle at which a pulse did not encounter a physical object is an angle at which the open sky is fully visible.

For example, with reference to FIG. **3**, the processor **66** executing the open sky data application **76** may determine that the open sky is visible at angles of 45°, 30°, 0°, −30°, −45°, and −60° within a plane that is perpendicular to the travel direction of the vehicle **30**. In another aspect, the processor **66** executing the open sky data application **76** may determine that each transmission angle at which a pulse occasionally encountered a physical object is an angle at which the open sky is partially visible. The processor **66** executing the open sky data application **76** may determine visibility of open sky at the given position in other manners as well.

At block **88**, the processor **66** executing the open sky data application **76** may use the video data associated with the given position to verify the determined visibility of open sky at the given position. In this respect, the processor **66** executing the open sky data application **76** may perform the verification using any technique now known or later developed. Further, block **88** is depicted in dashed lines to show that the processor **66** executing the open sky data application **76** may perform the verification optionally. In one aspect, the processor **66** executing the open sky data application **76** may perform the verification for positions at which physical features outside a range of the range-finding system **34** may obscure visibility of open sky (e.g., positions surrounded by tall build-

ings). The processor **66** executing the open sky data application **76** may perform the verification in other circumstances as well.

At block **90**, the processor **66** executing the open sky data application **76** may generate data representing the determined visibility of the open sky at the given position. In one aspect, the data representing the determined visibility of the open sky at the given position may include a value for each angle at which the open sky is visible from the given position. For example, with reference to FIG. **3**, the data representing the determined visibility of the open sky at the given position may include angle values of 45°, 30°, 0°, −30°, −45°, and −60°.

In another aspect, to reduce the required data storage space for the open sky data, the data representing the determined visibility of the open sky at the given position may include data indicating one or more ranges of angles at which the open sky is visible from the given position. The data indicating each range may include two angle values, each defining one end of the range of angles at which the open sky is visible from the given position. For example, with reference to FIG. **3**, the data representing the determined visibility of the open sky at the given position may include a range defined by angle values of 45° and −60°.

In yet another aspect, the data representing the determined visibility of the open sky at the given position may include data indicating a distance of a physical object at each edge of an open sky angle range. For example, with reference to FIG. **3**, the data representing the determined visibility of the open sky at the given position may include a distance of the building at an angle of 44.9° and a distance of the tree at an angle of −60.1°.

In still another aspect, the data representing the determined visibility of the open sky at the given position may include data indicating a visibility rating associated with the angles at which the open sky is visible from the given position. For example, for angles at which the open sky is determined to be only partially visible, the data representing the determined visibility of the open sky may include a rating of that partial visibility. The data representing the determined visibility of the open sky at the given position may take other forms as well.

At block **92**, the processor **66** executing the open sky data application **76** may store the data representing the visibility of the open sky at the given position into the data storage **68**. In one aspect, the processor **66** executing the open sky data application **76** may store the data representing the visibility of the open sky at the given position in an open sky data record that also contains an identifier of the given position. The processor **66** executing the open sky data application **76** may store the data representing the visibility of the open sky at the given position in other manners as well.

After generating and storing the open sky data for the given position, the processor **66** executing the open sky data application **76** may repeat the above process for various other positions in the geographic region **12**, which may be selected according to various criteria. In one aspect, the processor **66** executing the open sky data application **76** may generate and store open sky data for all positions at which data was collected. In another aspect, to reduce the required data storage space for the open sky data, the processor **66** executing the open sky data application **76** may generate and/or store open sky data for less than all positions at which data was collected.

For example, the processor **66** executing the open sky data application **76** may generate and store open sky data for specific positions on the road network **18**, such as at each node **22** and positions at predefined distances along road segments **20** (e.g., every 5 meters). As another example, the processor **66** executing the open sky data application **76** may generate open sky data for all positions on the road network **18** at which data was collected, but may only store open sky data for positions at which the open sky data indicates a significant change in visibility of the open sky (e.g., a change of 5° in one of the end point angles of the visibility range). The processor **66** executing the open sky data application **76** may employ similar selection criteria for positions off the road network **18** (e.g., pedestrian pathways). Other examples are possible as well.

Referring back to FIG. **4**, the processor **66** executing the open sky data application **76** may also perform the open sky data generation in other ways. For example, the processor **66** executing the open sky data application **76** may generate the open sky data based on GPS signal strengths collected by the data collection equipment **32** (e.g., via the positioning system **28**). Other examples are possible as well.

After the computing device **60** generates and stores the open sky data, the open sky data may be used for various purposes. In one example, as described below, the open sky data may be incorporated into a geographic database. In another example, as described below, the open sky data may be used to provide users with navigation-related functions and features. In yet another example, the open sky data may be used to improve map generation (e.g., by identifying a location of an overpass). In still another example, the open sky data may be used to identify potential locations for solar cell collectors. Many other examples are possible as well.

The data storage **68** may contain other applications as well. For example, the data storage **68** may contain a road-network data application that enables the processor **66** to generate and store data representing the road network **18** in the geographic region **12**. In another example, the data storage **68** may contain a points-of-interest data application that enables the processor **66** to generate and store data representing data representing points of interest surrounding the road network **18** in the geographic region **12**, such as businesses and facilities. In still another example, the data storage **68** may contain a pedestrian pathway data application that enables the processor **66** to generate and store data representing sidewalks, bike paths, etc. Other examples are possible as well.

III. Geographic Database

As described above, the geographic data generated by the computing device **60** may be incorporated into a geographic database. FIG. **6** depicts a geographic database **100**, according to an example embodiment. The geographic database **100** may be maintained in one or more data storage mediums, such as data storage of a computing device similar to the computing device **60** described above. As shown, the geographic database **100** may contain data **102** that represents geographic features in the geographic region **12**.

In one aspect, the geographic database **100** may contain data that represents the road network **18**. For example, as shown, the geographic database **100** may contain at least one road segment database record **104** (also referred to as "entity" or "entry") for each road segment **20** in the geographic region **12**. As another example, the geographic database **100** may contain a node database record **106** (or "entity" or "entry") for each node **22** in the geographic region **12**. The terms "nodes" and "segments" represent only one terminology for describing these physical geographic features, and other terminology for describing these features is intended to be encompassed within the scope of these concepts.

FIG. **7** shows some of the components of a road segment data record **104** contained in the geographic database **100**, according to an example embodiment. As shown, the road segment data record **104** may include or be associated with a

segment ID **104**(**1**) by which the data record can be identified in the geographic database **100** and data that indicates attributes of the represented road segment. The various attributes of a road segment may be included in a single road segment data record, or may be included in more than one type of road segment data record that cross-reference each other.

The data indicating the attributes of the represented road segment may take various forms. In one example, the road segment data record **104** may include or be associated with data **104**(**2**) that indicates the restrictions, if any, on the direction of vehicular travel permitted on the represented road segment. In another example, the road segment data record **104** may include or be associated with data **104**(**3**) that indicates a speed limit or speed category (i.e., the maximum permitted vehicular speed of travel) on the represented road segment. In yet another example, the road segment data record **104** may include or be associated with data **104**(**4**) indicating a classification of the represented road segment, such as whether the represented road segment is part of a controlled access road (e.g., an expressway), a ramp to a controlled access road, a bridge, a tunnel, a toll road, a ferry, and so on. In still another example, the road segment data record **104** may include or be associated with data **104**(**5**) identifying endpoints (e.g., geographic coordinates) of the represented road segment. In this respect, the data **104**(**5**) may include a link to node data records **106** that represent the endpoint nodes of the represented road segment. Further, the data **104**(**5**) may identify one endpoint as a reference node. In a further example, the road segment data record **104** may include or be associated with other data **104**(**6**) that indicates other attributes of the represented road segment. Other examples are possible as well.

FIG. **7** also shows some of the components of a node data record **106** contained in the geographic database **100**, according to an example embodiment. In one example, the node data record **106** may include or be associated with data identifying the represented node, such as data **106**(**1**) that provides the geographic coordinates (e.g., latitude and longitude) of the represented node. In another example, the node data record **106** may include or be associated with data **106**(**2**) identifying each road segment connected to the represented node. In yet another example, the node data record **106** may include or be associated with other data **106**(**3**) that indicates other attributes of the represented node. Other examples are possible as well.

Referring back to FIG. **6**, the geographic database **100** may also include other data records **108** that represent other kinds of geographic features or anything else in the geographic region **12**. For example, the other data records **108** may include point-of-interest data records that each contain data indicating attributes of a represented point of interest, such as a type (e.g., restaurant, hotel, city hall, police station, historical marker, ATM, golf course, etc.), a location, a phone number, and/or hours of operation of the represented point of interest. As another example, the other data records **108** may include pedestrian-pathway segment and node data records that are similar to the road segment and node data records. Other examples are possible as well.

The geographic database **100** may additionally include indexes **110**. The indexes **110** may include various types of indexes that associate different types of data contained in the geographic database **100** to each other or that associate to other aspects of the data contained in the geographic database **100**. For example, the indexes **110** may associate node data records **106** with road segment data records **104**. As another example, the indexes **110** may associate point of interest data records in the other data records **108** with road segment data records **104** and/or node data records **106**. Other examples are possible as well.

The open sky data generated by the computing device **60** may also be incorporated into the geographic database **100** and associated with the geographic data **102** in various manners. In one aspect, the geographic database **100** may maintain the open sky data in the other data records **108**. For example, the other data records **108** may include one or more open sky data records, each containing an identifier of a position (e.g., a segment ID and percentage from the segment's reference node) and data indicating the visibility of open sky (e.g., a range of angles at which the open sky is visible) at the represented position. One such data record **108** is shown in Table 1 and depicted visually in FIG. **8**.

TABLE 1

Segment ID	% From Ref Node	Min Angle	Max Angle
264098830	0%	−90	90
264098830	20%	−45	90
264098830	40%	−40	45
264098830	60%	−45	35
264098830	80%	−20	90
264098830	90%	−90	90

The open sky data records in the other data records **108** may then be associated with related road segment data records **104**, node data records **106**, and/or other data records **108** (e.g., point-of-interest data records, pedestrian-pathway data records, etc.) in various manners, such as via the indexes **110** and/or links in the records themselves.

In another aspect, the geographic database **100** may maintain the open sky data in the road segment data records **104**. For example, the other data **104**(**6**) in a road segment data record **104** may contain data indicating the visibility of open sky (e.g., a range of angles at which the open sky is visible) at one or more positions along the represented road segment **20**. Other examples are possible as well.

The geographic data **102** may also be organized in the geographic database **100** in various manners. In one example, the geographic data **102** may be organized into different subsets or types of data that relate to different navigation-related functions, such as routing data, cartographic data (for map display), maneuver data, points-of-interest data, and open sky data. In another example, the geographic data **102** may be organized into different layers that relate to different levels of detail. In yet another example, the geographic data **102** may be organized to facilitate spatial access. Other examples are possible as well.

IV. Navigation System

As described above, the geographic data generated by the computing device **60** and stored in geographic database may also be used by a navigation system to provide users with navigation-related functions and features. FIG. **9** is a block diagram of a navigation system **120**, according to an example embodiment. The navigation system **120** may be associated with a computing platform **122**, such as a vehicle-installed computing device, a personal digital assistant (PDA), a mobile telephone, a personal computer, or another computing device. The navigation system **120** is a combination of hardware and software components. As shown, the navigation system **120** may include a user interface **124**, a communication interface **126**, and a positioning system **128**, each opera-

tively coupled to a processor **130** and data storage **132**. The navigation system **120** may include other components as well.

The user interface **124** may function to facilitate user interaction with the navigation system **120**, such as by allowing a user to input information into the navigation system **120** and obtain information from the navigation system **120**. In this respect, the user interface **124** may include or provide connectivity to various input components, such as a touch screen and/or a microphone for instance. The user interface **124** may also include or provide connectivity to various output components, such as a display screen and/or a speaker for instance. The user interface **124** may include or provide connectivity to other components for facilitating user interaction with the navigation system **120** as well.

The communication interface **126** may function to communicatively couple the navigation system **120** to one or more other devices, such as a device maintaining the geographic database **100**. In this respect, the communication interface **126** may take the form of one or more interfaces that provide for wireless and/or wired communication with another device, such as an Ethernet interface, a serial bus interfaces (e.g., Firewire, USB 2.0, etc.), a chipset and antenna adapted to facilitate wireless communication according a desired protocol, or any other such interfaces now known or later developed. Other configurations are also possible.

The positioning system **128** may function to track and generate position data representing a position of the computing platform **122**. In this respect, the positioning system **128** may employ any technology now known or later developed, including GPS-type technology, dead reckoning-type technology, or a combination of these or other technologies, all of which are known in the art. Further, the positioning system **128** may include various components, including a GPS receiver, an IMU, and/or any other device that enables tracking of the computing platform's position. Further yet, the position data may take various forms, including data indicating geographic coordinates (latitude, longitude, and altitude), direction, orientation, and/or speed of the computing platform **122** for instance.

The processor **130** may function to execute or interpret program instructions (which may be arranged into an application) that enable the processor **130** to carry out various tasks, including tasks related to providing navigation-related functions and features. In this respect, the processor **66** may take the form of one or more processor components, such as general-purpose processors (e.g., a microprocessor), application-specific processors (e.g., an ASIC or DSP), programmable logic devices (e.g., a FPGA), or other processor components now known or later developed. Other configurations are possible as well.

The data storage **132** may function to store various types of program instructions and data that can be read by the processor **130**, such as applications, geographic data, and/or data from the user interface **124**, the communication interface **126**, and/or the positioning system **128**. In this respect, the data storage **132** may take the form of one or more data storage mediums, such as volatile data storage mediums (e.g., RAM, registers, and/or cache) and/or non-volatile data storage mediums (e.g., ROM, a hard disk drive, a solid state drive, flash memory, an optical storage device, and/or a floppy disk). Some data storage mediums may be integrated in whole or in part with the processor **130**. Further, some data storage mediums may be external to and/or removable from the navigation system **120**, and may interface with the navigation system **120** in various manners (e.g., via the communication interface **126**, a drive, or a reader). Other configurations are possible as well.

The data storage **132** may contain a geographic database **134**, which may be generated from the geographic database **100** described above. The geographic database **134** may be in various formats, such as a graphical data file (GDF) or a standard interchange format (SIF). In one embodiment, the geographic database **134** may be a geographic database published by NAVTEQ North America, LLC of Chicago, Ill. The geographic database **134** may be stored in various components of the data storage **132**. For example, the geographic database **134** may be stored in a non-volatile data storage medium (e.g., a hard disk drive or a removable storage component installed in a drive) and then loaded into a volatile data storage medium (e.g., RAM) when operated on by the processor **130**. Other examples are possible as well. In an alternative aspect, the geographic database **134** may be stored remotely from the navigation system **120**, in which case the navigation system **120** may access the geographic database **134** via the communication interface **126**. Other examples are possible as well.

The data storage **132** may contain one or more applications that enable the processor **130** to perform various tasks related to providing navigation-related features and functions to a user. When executing the one or more applications, the processor **130** may use data from the geographic database **134** and perhaps data from the user interface **124**, the communication interface **126**, and/or the positioning system **128**. The one or more applications may be stored in various components of the data storage **132**. For example, the one or more applications may be stored in a non-volatile data storage medium (e.g., a hard disk drive or a removable storage component installed in a drive) and then loaded into a volatile data storage medium (e.g., RAM) when operated on by the processor **130**. Other examples are possible as well.

In one aspect, the data storage **132** may contain a map display application **136** that enables the processor **130** to display a map of the geographic region **12** (or a portion thereof) to a user. In conjunction with the display application **136**, the data storage **132** may also contain a positioning application **138** that enables the processor **130** to display the computing platform's current position on a map.

In another aspect, the data storage **132** may contain a route calculation application **140** that enables the processor **130** to determine a route from an origin to a destination. For example, the processor **130** executing the route calculation **138** may determine a route from the computing platform's current position as determined via the positioning system **128** to a position input by a user via the user interface **124**. Other examples are possible as well. In conjunction with the route calculation application **140**, the data storage **132** may also contain a route guidance application **142** that enables the processor to provide a user with detailed directions for reaching the destination.

In yet another aspect, the data storage **132** may contain an open sky application **144** that enables the processor **130** to use the open sky data for various purposes. For example, the processor **130** executing the open sky application **144** may use the open sky data to identify positions having good or bad visibility of the open sky. In this respect, the processor **130** executing the open sky application **144** may also provide a user with an identification of the positions having good or bad visibility via the user interface **124**.

In another example, the processor **130** executing the open sky application **144** may use the open sky data and perhaps other data (position data, date/time, and/or GPS satellite

information) to determine GPS signal availability information for various positions, such as the computing platform's current position and potential future positions. For instance, the processor **130** executing the open sky application **144** may determine which GPS satellites are currently visible and where those satellites will become obstructed; which GPS satellites are currently obstructed and where those satellites will become visible; where GPS signals will be completely unavailable; and where GPS signals will experience multipath errors. Using this information, the processor **130** executing the open sky application **144** may anticipate and perhaps compensate for a loss or degradation of GPS signals. The processor **130** executing the open sky application **144** may also provide a user with GPS signal availability information via the user interface **124**.

In a similar example, the processor **130** executing the open sky application **144** may use the open sky data and perhaps other data (position data, date/time, and/or radio antenna information) to determine radio signal availability information for various positions, such as the computing platform's current position and potential future positions. For instance, the processor **130** executing the open sky application **144** may determine which radio antennas are currently visible and where those antennas will become obstructed; which radio antennas are currently obstructed and where those antennas will become visible; where radio signals will be completely unavailable; and where radio signals will experience multipath errors. Using this information, the processor **130** executing the open sky application **144** may anticipate and perhaps compensate for a loss or degradation of radio signals. The processor **130** executing the open sky application **144** may also provide a user with radio signal availability information via the user interface **124**.

In another example, the processor **130** executing the open sky application **144** may use the open sky data and perhaps other data (e.g., position data, date/time) to determine exposure to weather conditions (e.g., sun, rain, snow) at various positions, such as the computing platform's current position and potential future positions. Using this information, the processor **130** executing the open sky application **144** may provide a user with an identification of (and perhaps directions to) positions that are exposed to or sheltered from a given weather condition, both on and off the road network **18**. For instance, the processor **130** executing the open sky application **144** may provide a user with an identification of a parking location that is sheltered from weather conditions. Additionally, using this information, the processor **130** executing the open sky application **144** may also identify positions at which sun glare may affect drivers.

As described above, the processor **130** executing the open sky application **144** may use the open sky data for various purposes, such as providing a navigation system user with information regarding visibility, GPS or radio signal strength, and sun glare. The processor **130** may execute the map display application **136**, the route calculation application **140**, and/or the route guidance application **142** in conjunction with the open sky application **144**. As a result, the processor **130** may provide navigation guidance to the user that allows the users to select and obtain guidance for traveling a route based on open sky data. For example, the user may select a route that has the best GPS signal availability or avoid a route with limited visibility.

In a related example, the processor **130** executing the open sky application **144** may use the open sky data and perhaps other data (e.g., position data, date/time) to predict solar energy at various positions, such as the computing platform's current position and potential future positions. Using this information, the processor **130** executing the open sky application **144** may provide improved route guidance to solar powered cars. Other examples are possible as well.

It is intended that the foregoing detailed description be regarded as illustrative rather than limiting and that it is understood that the following claims including all equivalents are intended to define the scope of the invention. The claims should not be read as limited to the described order or elements unless stated to that effect. Therefore, all embodiments that come within the scope and spirit of the following claims and equivalents thereto are claimed as the invention.

I claim:

1. A navigation system comprising:

a processor;

data storage that is operatively coupled to the processor;

open sky data entities stored in the data storage and accessible by the processor, wherein each open sky data entity represents a visibility rating of open sky at a respective position;

road-network data entities stored in the data storage and accessible by the processor, wherein each road-network data entity represents a road network at the respective position, and wherein the open sky data entities and the road-network data entities are associated based on position; and

program instructions stored in the data storage and executable by the processor for receiving a route request including a starting location, a destination, a visibility preference, and responsive thereto, using the road-network data entities to generate a route based on the visibility preference and the visibility rating of open sky for the road-network data entities; wherein the route is generated by calculating a path between the starting location and a destination using the visibility preference to select road-network data entities.

2. The navigation system of claim **1**, further comprising:

a points-of-interest data application in the data storage and accessible by the processor, wherein the points-of-interest data application enables the processor to generate and store data representing points of interest surrounding a road network in a geographic region.

3. The navigation system of claim **1**, further comprising:

a pedestrian pathway data application in the data storage and accessible by the processor, wherein the pedestrian pathway data application enables the processor to generate and store data representing sidewalks, bike paths, and pedestrian walkways.

4. The navigation system of claim **1**, further comprising:

a control application in the data storage and accessible by the processor, wherein the control application enables the processor to control a range-finding system, a video-capture system, and a positioning system.

5. The navigation system of claim **1**, further comprising:

program instructions stored in the data storage and executable by the processor for using the open sky data entities to determine an availability of a signal at one or more positions.

6. The navigation system of claim **5**, wherein the signal is a global positioning system (GPS) signal.

7. The navigation system of claim **5**, wherein the signal is a radio signal.

8. The navigation system of claim **1**, wherein the route is determined based on exposure to weather conditions.

9. The navigation system of claim **1**, wherein the route is determined based on availability of solar energy.

10. The navigation system of claim **1**, wherein the route is determined based on access to covered parking locations.

11. The navigation system of claim 1, wherein the route is determined based on open sky exposure for bike paths or pedestrian walkways.

12. An apparatus comprising:

at least one processor; and

at least one memory including computer program code for one or more programs;

the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to at least perform:

accessing open sky data entities stored in the data storage and accessible by the processor, wherein each open sky data entity represents a visibility rating of open sky for a road segment;

receiving location data, a destination, and a visibility preference;

generating a route using the location data, the destination, and open sky data entities that satisfy a visibility preference; and

providing data representing the visibility of open sky for each road segment included in the route.

13. The apparatus of claim 12, wherein the computer program code is configured to cause the apparatus to at least perform:

determining an availability of a signal based the open sky data entities.

14. A non-transitory computer readable medium having a computer program stored thereon, the computer program comprising:

identifying open sky data entities each representing visibility of open sky of a road segment at a respective position;

processing geographic data entities each representing a geographic feature at a respective position;

associating the open sky data entities and the geographic data entities based on position;

generating a route; the route using the open sky data entities; and the geographic data entities; wherein the route selects one or more road segments which surpass a threshold of visibility of open sky.

15. The non-transitory computer readable medium of claim 14 further comprising:

determining an availability of a signal based on the open sky data entities.

16. The non-transitory computer readable medium of claim 15 wherein the signal is a global positioning system (GPS) signal.

17. The navigation system of claim 1, further comprising:

program instructions stored in the data storage and executable by the processor for using the open sky data entities to predict solar energy at the respective position; and

wherein the route is generated to improve solar availability for a solar powered vehicle.

18. The navigation system of claim 5, wherein the route is determined based on the availability of the signal.

19. The navigation system of claim 1, wherein the visibility rating includes a partial visibility rating associated with the one or more angles at which the open sky is partially visible from the position.

20. The navigation system of claim 1, wherein the route is configured to identify an overpass based on the open sky data entities.

* * * * *